A STUDY OF DESIGNING AN INQUIRY-BASED UNIT IN MATHEMATICS AND SCIENCE

By

PATTI DYJUR * QING LI **

* Ph.D Candidate, University of Calgary.
** University of Calgary.

ABSTRACT

This paper looks at the design process of an inquiry-based mathematics and science unit in two urban grade nine classes. Three teachers who teach in an urban, all-girls' Junior high school collaborated with math/science and educational experts to design and implement the unit. Results showed the following: teachers needed to be flexible regarding the direction of the unit, collaborating with experts helped teachers to design a more authentic unit, topic selection needed to be carefully considered, and that the resulting unit was worthwhile due to its relevance, richness, and increased student interest and ability to make multi disciplinary connections. Issues with this approach included workload, the amount of time required for planning, and a lack of inquiry-based materials in math.

Keywords: Instructional Design, Inquiry Based Learning, Math and Science Learning.

INTRODUCTION

This paper focuses on the instructional design process of an inquiry-based mathematics and science project for two grade nine classes. A collaborative team of three grade nine teachers, a university professor, and a scientist designed and implemented multi disciplinary, inquiry-based units for the two classes. The design team used an iterative approach, incorporating feedback from students during the delivery of the unit.

Inquiry-based learning is generally recognized as being more authentic for students as it allows them the flexibility to make some of the decisions about their learning; an emphasis on inquiry also tends to promote critical thinking skills. As a result, students may have deeper, more relevant learning experiences when using this approach. The body of literature on inquiry-based learning in the secondary grades is growing, yet very few studies focus on inquiry in math and science. This study extends our understanding of inquiry in a secondary educational setting. Additionally, it adds a fresh perspective since the project uses experts in math and science to collaborate with classroom teachers in the design of the project.

Related Literature

The theoretical framework for this study is constructivism with a focus on inquiry-based learning. Rooted in constructivism, inquiry-based learning promotes student learning "through guided and increasingly independent investigation of complex questions, problems, and issues, often for which there is no single answer". Knowledge is socially constructed and learning occurs in the involvement in communities of practice.

One of the major assumptions underlying constructivism is the idea that knowledge is not factual information just waiting to be discovered, but rather, it is a human product that is constructed based on each person's experience. As we all have different experiences, individual meaning may be quite different from the understanding that other people have created (Gordon, 2009; Meyer, 2008). Related to this concept is the assumption that reality is a social construct, rather than an objective entity. Thus, there is no single truth that can be accepted by everyone. As reality is interpreted based on people's individual experiences, and is embedded in contextual factors such as culture, gender, age, and so on, we will never arrive at a universal understanding of reality (Gordon, 2009; Meyer, 2008; Cronje, 2006). Another assumption of constructivism is that learning is a social process. People collaboratively create meaning and refine their understanding as they interact with others and with their learning environment (Gordon, 2009; Lin & Matthews, 2005; Phillips, 1995).

According to Vygotsky (1962, in Lin & Matthews, 2005), learning occurs in a social context, with individuals arriving at personal meaning based on their own experiences.

Rooted in John Dewey's work, inquiry-based learning is "an approach to learning that involves a process of exploring the natural or material world, and that leads to asking questions, making discoveries, and rigorously testing those discoveries in the search for new understanding" (National Science Foundation, 2005, p. 2). Inquiry, according to Dewey, "is the only authentic means at our command for getting at the significance of our everyday experiences of the world in which we live" (1938, p. 111). Promoting learning from guided exploration of complex problems and issues via direct experience and inspiring their natural curiosity (Lee, 2004), inquiry is also an essential skill for coping with the complexity of this information age and its many challenges such as information overload (National Science Foundation, 2005).

Although inquiry is not a new idea, it was not until the 1980s that people started to realize the value of inquiry-based learning. The current enthusiasm in inquiry has resulted in a flurry of research studies, each with its own definition and understanding of the term. Some studies focused on learning activities and others emphasized inquiry as a teaching technique. Regardless of the focus, it is commonly accepted that inquiry can embrace different approaches ranging from structured inquiry, to guided and open inquiry. Inquiry-based learning encourages collaborative learning, the use of examples that grow out of the students' own experiences, appreciation of diversity, and connecting with experts in the fields. In this paper, the authors define inquiry as "an approach to learning that involves a process of exploring the world, and that leads to asking questions, making discoveries, and rigorously testing those discoveries in the search for new understanding".

According to the Galileo Educational Network, several characteristics are generally presented in inquiry-based learning. Projects focus on authentic problems and issues that are relevant to students and to the real world. Students play a key role in defining the questions to be studied as well as the direction that learning takes. Learning is done through field work, design, construction, interviews, research, and other types of active exploration that lead students to new insight; deep understanding is the goal, not regurgitation of facts. Teachers facilitate the learning process by guiding students and structuring the learning environment. Lord and Orkwiszewski note that inquiry-based learning differs from a didactic, prescribed approach in that problems are more ill-defined and may have several possible solutions.

Inquiry-based learning has been used to teach various subjects, including mathematics, science, language arts, and health education. A growing body of research is starting to provide evidence that inquiry-based learning can have a positive impact on student learning that is reflected in their academic achievements and their ability to solve problems. Many current mathematics and science standards are theoretically grounded in constructivism. Consequently, examples of successful standards-based instruction are often characterized as inquiry-based.

Inquiry in the math/science classroom is characterized by hands-on activity and critical thinking. Students are encouraged to explore, do research, reflect on what they have learned, communicate their findings, and evaluate their knowledge. Unlike the scientific method, in which students follow a prescribed routine, scientific inquiry prompts students to ask interesting questions, plan and conduct investigations, use appropriate techniques to gather data, think critically about evidence and possible explanations, analyze alternative explanations, and communicate their arguments. Benefits of using an inquiry approach include increased retention of factual knowledge, more flexibility/creativity in problem solving, and an increase in student motivation.

Various scholars note that there can be challenges in implementing inquiry-based learning in the math/science classroom. One such difficulty is that it requires substantially more time to teach this way than more traditional methods (Cronje, 2006). Another challenge is the demands placed on teachers: they need to know the science content, have an understanding of how scientists work in their field, know how to implement inquiry-based learning pedagogy, and have the technological expertise to support students in their investigations (Harris & Rooks, 2010). These concerns are not trivial considering the heavy workload that most teachers already have; some teachers indicate that inquiry-based learning requires too much time and effort of them (Baker et. al., 2008). Students can find inquiry-based learning challenging as well; those who have limited experience with this type of pedagogy can find the shift in expectations, to a more self-directed learning environment, quite frustrating (Harris & Rooks, 2010; Knodt, 2009). Finding support materials for the inquiry-based science classroom can be tricky as well. If teachers are to rely on materials other than textbooks, then they must find authentic, engaging, age-appropriate resources such as news articles, literature, and various types of scientific writing. Certain scientific topics have a greater variety of readily accessible materials than others (Ford 2009).

Researchers note that collaborative design can be challenging for educators. Many teachers are accustomed to planning in isolation; team planning requires them to see other viewpoints, incorporate other people's ideas, and perhaps use a different planning process. It is also essential that team members build a level of trust, which might require some time to establish. The entire team needs to have good communication skills and a shared vision for the project. Frequently, an additional challenge is an increase in workload for the teacher .

The benefits of collaborative design can make it worthwhile to overcome the challenges, though. In one study, teachers felt that the collaborative design process was a wonderful professional development opportunity in that it triggered reflection on their teaching strategies, which led to some changes in teaching approach . Researchers of another study noted that the multidisciplinary, collaborative design approach led to changes in the teachers' classroom practices, which positively influenced student learning outcomes and thereby had an impact on the teachers' beliefs and attitudes. These studies support the finding that individuals bring different strengths to the team, resulting in an enhanced design. A collaborative approach can facilitate the exchange of ideas, provide mentorship, and prompt people to reflect on their assumptions. Team planning can lead to greater integration of topics, and for students, a better understanding of subject matter. Enhanced student learning can provide a compelling rationale for using a collaborative planning approach.

Research Questions

This study explores the process of designing inquiry-based math and science units for grade nine. Specifically, the following research questions guide this study:

- How did the collaborative design among teachers, researchers, and scientists impact on the design of the inquiry-based math and science units?
- What are teacher perceived negative aspects of such collaborative design process?

During the term, the participating teachers held weekly meetings with teacher educators, researchers and a scientist to discuss and design learning activities. Preliminary meetings were exploratory in nature, with brainstorming sessions to generate activity ideas. The team first developed an overarching theme to guide students' learning during the term. In subsequent meetings, the design team mapped out how learning activities related to the curriculum, saving the best and discarding ideas that held less relevance. A total of three inquiry projects were implemented for the semester, each project lasting four to six weeks. The design of these projects focused on connecting learning with students' lives through the exploration of diverse perspectives. During this process, students provided ongoing feedback which was incorporated into the design of subsequent learning activities.

Methods

This research was a qualitative case study of three grade nine teachers who were teaching in an urban school in Western Canada. The case focused on their experiences designing inquiry-based math/science units in collaboration with scientists/mathematicians, researchers, and an external pedagogy consultant. The participants had a range of teaching experience, including a beginning teacher (N), one who had been teaching for several years (M), and a teacher with more than 20 years of experience (A). They all were teaching at the same junior-high all-girls' school.

Data

Data collected included interviews of the teachers at the beginning, middle, and the end of the project. Notes were taken during weekly 2-3 hour meetings involving the teachers, researchers, an external pedagogy consultant, and a scientist. Occasionally, meeting notes were taken by more than one person. Further, the authors conducted monthly observations of classroom teaching of each teacher and interviewed each of 18 students at least three times. They also collected individual reflective field journals kept by the teachers, recording their actions, plans, and reflections. Additional data included a field diary by the researchers. Student interviews also generated some illuminating comments about the learning units.

Analysis

Authors independently conducted initial coding of the field notes, interview transcripts, and teacher reflective journals to identify the major themes. These initial codes were then compared, discussed, and continued to be revised during the interaction with data until mutually agreed themes were developed. The initial list of codes was then reexamined, and the codes pertaining to the teacher professional development, as described in the relevant literature, were isolated. Grouping the data under different codes allowed us to see different patterns and themes emerging. Through repeated scrutiny, the original contextualized descriptive codes were refined to five more abstract constructs: teacher beliefs about inquiry, students, collaboration, and technology, and resulting teacher practice. These different themes were interpreted within the broader social context of the school. To ensure reliability and accuracy, they employed strategies including the analysis of different forms of data, including student interviews and the researchers' field diaries to triangulate the interviewees' claims. Also, the data was analyzed independently by three researchers, looking for extreme cases, and paying particular attention to negative evidence.

Results

Qualitative analysis was conducted from teacher interviews, student interviews, and researchers' journals. The emergent themes shed light on many facets of inquiry learning in math and science, as well as student and teacher roles.

Impact on Design

A focus on inquiry demanded that teachers be flexible with their planning. They had a starting point for the unit of study and a direction for students to guide their inquiry, but teachers also had to be ready to delve into areas that interested the students. This was necessary if students were going to take ownership of the learning.

The authors planned the whole unit, they sat and said these are the curriculum objectives that they are going to try to cover every week, but then it changes... because they didn't really know where they were going to go until they saw where it was going with the kids, so that's the tricky part [M, mid-interview].

The flexibility with planning allowed the teachers to use formative assessment which helped them to determine next steps in designing the unit. With this information they were able to customize the learning to some extent for students who wanted to study it at a deeper level:

> *[The projects are] really creative and it's different for every kid. The kids that need enrichment, they can take it further, into more depth... The kids that are really keen on it and want that enrichment, they can go find further stuff, more information than they would do as a whole class at an introductory level [M, mid-interview].*

Collaborating with math/science and educational experts, teachers were able to create authentic units that applied to the real world. The classroom teachers appreciated having different perspectives on the content and the ways in which their collaborators were able to make connections:

- *I liked the follow-up with [the math/science and educational experts], in terms of where we were, how can we make it better... I liked linking it back to what we're doing here and making sure what we're doing next still links into our studies. That's been the fun part of it, making it all fit in authentic ways [N, mid-interview].*
- *In terms of [the math/science experts] coming in with their background, and offering perspectives that we*

wouldn't have thought of before and [the educational expert] bringing in the inquiry, just the way she will bring ideas and make connections for us, the more people you have to do that, the richer and broader and the more possibilities you have [A, mid-interview].

Teachers identified a lack of resources as one of the challenges of implementing an inquiry-based approach in math and science. Since these subjects have not traditionally been taught in this way, the teachers had difficulty finding appropriate resources for the students. They also voiced the frustration that very few of their peers took an inquiry-based approach in math and science, and therefore it was difficult to find other teachers who could provide support.

Having math/science experts on the team, therefore, helped the classroom teachers to make connections, within subject areas, among different disciplines, and between curricular topics and real life application. Such connections were enriching and often beyond the teachers' subject matter expertise. Further, the math/ science experts identified appropriate resources.

- *[The experts] made a lot of connections that we didn't even think of. We said, this is what we're working on, can you see any connections, and they saw it and gave us some support to find those resources [M, post-interview].*
- *Resources are tough, just to find all of that stuff. Sometimes you think, "This would be great," if I could find information on this, and all those things just take forever. We're thinking about GPS, but didn't really know where to make those connections and where to find the information. The really great thing was, [the scientist]... helped to do that for us, so that really, really, really helped. We couldn't really find anything, we weren't really sure, we didn't have the expertise in it [N, mid-interview].*

The classroom teachers noted that while planning with their colleagues was time-consuming, it was also worthwhile. Collaboration allowed them to draw on each other's strengths, bringing different things into the classroom:

- *I think that there have been really constructive pieces that have come out of [the planning sessions]... and I've been able to draw links into Language Arts and Social Studies in various ways [N, mid-interview].*
- *Her strengths and my strengths are different, and if we were together, we could draw on those strengths and be a fantastic team... [A colleague] has far greater knowledge in terms of mathematics and science than I do, and I have greater experience with inquiry than she does, so if we could marry those in the classroom it would be so powerful [A, mid-interview].*

Another theme that emerged from the data was that planning an inquiry-based unit required careful topic selection. The teachers asserted that the topic had to be broad, but carry weight. In order to hold student interest, it needed to be current, relevant, and authentic. They said they would do the same unit next year, if the topic was still current and they could bring something fresh to it:

- *Would I do a bear inquiry every year from now on if I taught Grade 9? No, but I would do a bear inquiry again next year if again it becomes hot. Is there value to do it again next year? For my partner, a hundred percent. There is the recursive nature for her to see it, ... to see how you have to bring what's fresh into it [A, post-interview].*

The teachers emphasized that current topic selection was critical to attracting student attention in that it connected learning to their own lives. The teachers wanted to maintain the same structure for the unit in future years, while focusing on different ideas that are predominant issues at the time. Selecting a relevant topic for inquiry was more critical to them than conserving on preparation time by reusing a unit.

Because of the focus on inquiry-based learning, the design of the experiences had to reflect different roles for teachers and students than they were accustomed to in a traditional classroom. Students were no longer passive learners that follow prescribed routines and topics of study. Rather, they had to be more self-directed, formulating their own questions and doing research, and ultimately deciding where the unit would end up.

- *Kids need to experience their learning. They need to be the ones that are directing it to some degree. In* *terms of asking questions, and formulating their ideas around it [A, mid-interview].*

In alignment with this approach, teachers also had to assume a different role in the classroom, providing a starting point and a guiding hand, while maintaining the flexibility to let students make decisions:

- *As a teacher, I guide that process, asking guiding questions to get them to go where they need to go in terms of making the answers correct, are their assumptions correct, but not limiting that to what's given in the curriculum, what's given by my own knowledge, but expanding beyond that [N, mid-interview].*

Therefore, teachers had to be willing to give some control over to the students, letting them make some of the learning decisions.

The three teachers in the project concurred that this inquiry-based, collaborative approach was critical to the students' success of making real-world connections with math and science learning. Students sometimes see math, in particular, as disconnected from the real world and have no practical application. The math/science experts were able to add relevance and richness, which increased interest in the subjects and allowed students to make multidisciplinary connections. One teacher noted that:

- *They're more aware of what's current and they have now the knowledge and the content to back up their thinking, and I think they're surprised in how informed they've become. An example was when [a guest] came in to do the bear presentation, the kids' questions blew her out of the water. It wasn't just surface level questions, it was deeper questions [A, mid-interview].*

Incorporating student feedback during the delivery of the unit allowed teachers to address student comments, especially negative comments or concerns that students had. As a result, the overall learning experience for students was strong and relevant.

Negative Results

There were a few issues that arose with this approach to design. One such issue was that the unit could not always be delivered in the ways that it was designed. Various constraints arose, forcing the teachers to make compromises. One of the largest constraints was time: implementing an inquiry-based unit in math and science takes a lot of it. The teachers felt pressured to keep up a certain pace so that they covered the curriculum in a timely manner. The teachers also felt pressure from parents who were not accustomed to this learning approach:

- *I've had some discussions with one student in particular and her mother about the different approach to assignments and the need to think outside of the regurgitation that she perhaps was used to in the past… those kinds of conversations have been a bit of a struggle for sure [N, mid-interview].*

Another issue with using this approach was teacher workload issues. All three teachers stated that the planning process took more time; though the end result was worth it, the workload was definitely increased. In addition to meeting with the math/science and educational experts, the teachers themselves met frequently to discuss the unit's direction:

- *We get together all the time because we try to keep things the same and I actually go over and sit in her class just to try to keep things uniform between the two classes. We usually get together on the weekends and plan for the week, plan for the month, where are we going, what we are doing. Sometimes it's hard because we get so busy and then things don't go as well [M, mid-interview].*

Discussion

A significant aspect of the study is how the design team incorporated student suggestions throughout the iterative design process. The classroom teachers continually assessed student learning and interest, requesting feedback, and revising the project accordingly. This is in contrast to the way in which some teachers design the learning for their students: a rigid, predetermined sequence of instruction with little consideration for student interests. Classroom teachers, administrators, and instructional designers will find the focus on collaborative, iterative design to be of interest.

The need for flexibility is the first theme identified in this study that speaks to the nature of designing inquiry-based learning. This flexibility is reflected in the learning design and exercised throughout the learning experience. When teachers, scientists and researchers collaboratively plan their instructions, they need to incorporate a certain level of flexibility so that teachers can make necessary changes to accommodate student needs. Formative assessments can provide salient information that reveals what has been working well and areas for improvement in student learning. These important data therefore need to be integrated into the iterative design of the subsequent instructional activities.

Flexibility is also required in the unit planning to allow students' input in order to facilitate student direction regarding the content. When students have a voice in their studies, including the activities and the content, the learning process becomes intrinsically motivating for them. Allowing students to find their relevance in math and science topics necessitates that the teachers give up some of the control of the direction of the learning experience. Teachers need to be prepared to let students make their own decisions and take advantage of serendipitous learning. The nature of an inquiry based approach also demands the changing of student roles from passive listeners to active participants. They need to take charge of their learning by selecting activities that have meaning to them and exploring avenues of interest along the way, carefully guided by the teachers.

Results of this study also suggest that good instructional design for inquiry-based learning demands careful topic selection. Current authentic topics, relevant to students and broad enough to pull in multidisciplinary connections, provide meaningful context for learning. Topic selection is enhanced by incorporating the expertise of the scientists/mathematicians because it allows both teachers and students to benefit from their depth of knowledge and experience. Both teachers and students in the study noted that the unit was authentic and relevant to their lives. Through careful planning, the teachers guided students to make multidisciplinary connections, leading to deeper learning that have gone well beyond curriculum expectations.

A significant strength of the collaborative design with experts in math/science is that the experts can make connections between the subjects and the real world that goes beyond the scope that regular classroom teachers can provide. In this study, the teachers feel that the scientists have provided useful connections and resources that they had not thought of or outside of their knowledge and experiences. These connections are vital for students to understand the application of math and science to everyday life and the real world. This finding confirms that a collaborative approach to design can facilitate integration of different topics and real applications .

Conclusions

This paper explores the collaborative design process of an inquiry-based mathematics and science unit in two urban grade nine classes. The study adds to the body of research in a couple of key areas. First of all, few research studies have been conducted on designing the learning environment for inquiry in secondary math and science classrooms; math is especially neglected. The results of this study add to our theoretical understanding of the nature of inquiry in secondary education. Additionally, the results provide practical guidelines to teachers at the secondary level who are interested in designing inquiry-based projects in math and science.

Although there are numerous benefits, the results from this study show that a collaborative design process of inquiry-based instruction has challenges. One challenge is the extensive time required to plan and create engaging learning experiences. More time is required of the teacher to organize resources, structure teaching and learning activities, and conduct student assessment for coherent and authentic inquiry math and science units. In connection with the amount of time required, teacher workloads have increased with this approach. This is consistent with previous research that indicates an increased workload for teachers. One implication is that administrators should be supportive of teachers' efforts to incorporate collaborative design of inquiry based instruction to their classrooms. Some suggested strategies include course release time and professional development on inquiry-based instruction.

There are a couple of limitations of the study worth noting. First of all, the study was conducted at an all-girls' school. Since this is a specific population, the authors do not know if the results would be comparable in a mixed-gender setting. Another limitation of the study is the climate of support. Administration in this school was very supportive of inquiry-based learning and teacher collaboration, encouraging teachers to plan together and meet with external experts. Teachers who are in a less supportive environment get different results from the study.

References

[1]. **Amaral, O., Garrision, L., & Klentschy, M. (2002).** Helping English learners increase achievement through inquiry-based science instruction. *Bilingual Research Journal, 26*(2), 213-239.

[2]. **Baker, W. P., Barstack, D. C., Clark, D., Hull, E., Goodman, B., & Kook, J. (2008).** Writing-to-learn in the inquiry-science classroom: Effective strategies from middle school science and writing teachers. *Clearing House: A Journal of Educational Strategies, Issues and Ideas, 81*(3), 105-108.

[3]. **Carter, A. (2004).** Autonomy, inquiry and mathematics reform. *The Constructivist*, *15*(1), 1-15.

[4]. **Colburn, A. (2000).** An inquiry primer. *Science Scope,* 2000(March), 42-44.

[5]. **Cronje, J. (2006).** Paradigms regained: Toward integrating objectivism and constructivism in instructional design and the learning sciences. *Educational Technology Research & Development*, *54*(4), 387-416.

[6]. **Dewey, J. (1938).** *Experience and education*. NY: Collier.

[7]. **Elmore, R. (2000).** *Building a new structure for school leadership.* The Albert Shanker Institute.

[8]. **Fang, Z., L. Lamme, et al. (2008).** "Integrating reading into middle school science: What we did, found, and learned." *International Journal of Science Education 30*(15): 2067-2089.

[9]. **Ford, D.J. (2009).** Promises and challenges for the use of adapted primary literature in science curricula: Commentary. *Research in Science Education*, *39*(3), 385-390. doi: 10.1007/s11165-008-9115-8.

[10]. **Galileo Educational Network. (2008).** *What is inquiry?* Retrieved Sept. 23, 2008, from http://www.galileo.org/inquiry -what.html

[11]. **Gerber, B.L., Price, C., Barnes, M., Hinkle, V., Barnes, L., Gordon, P., et al. (2003, March).** Excellence in rural science teaching: Examining elements of professional development models. Paper presented at the *Annual meeting of the National Association for Research in Science Teaching,* Philadelphia, PA.

[12]. **Gordon, M. (2009).** Toward a pragmatic discourse of constructivism: Reflections on lessons from practice. *Journal of the American Educational Studies Association*, *45*(1), 39-58. doi: 10.1080/00131940802546894.

[13]. **Harris, C.J. & Rooks, D.L. (2010).** Managing inquiry-based science: Challenges in enacting complex science instruction in elementary and middle school classrooms. *Journal of Science Teacher Education*, 21, 227-240. doi: 10.1007/s10972-009-9172-5.

[14]. **Kleiman, G. M. (2005).** *Does technology combined with inquiry-based lessons increase students' learning?* Retrieved September 19, 2006, from http://cosn.org/resources/edc/vol_1.pdf.

[15]. **Knodt, J.S. (2009).** Cultivating curious minds: Teaching for innovation through open-inquiry learning. *Teacher Librarian, 37*(1), 15-16.

[16]. **Lave, J., & Wenger, E. (1991).** *Situated learning: Legitimate peripheral participation.* New York: Cambridge Press.

[17]. **Lee. (2004).** Promoting learning through inquiry. *Essays on Teaching Excellence: Toward the Best in the Academy*, *15*(3), 1-5.

[18]. **Lin, C.H. & Matthews, R. (2005).** Vygotsky's philosophy: Constructivism and its criticisms examined. *International Education Journal, 6*(3), 386-399.

[19]. **Lord, T., & Orkwiszewski, T. (2006).** Moving from didactic to inquiry-based instruction in a science laboratory. *American Biology Teacher, 68*(6), 342-345.

[20]. **Mahony, M., Wozniak, H., Everingham, F., Reid, B., & Poulos, A. (2003).** Inquiry-based teaching and learning: What's in a name? Paper presented at the *HERDSA.*

[21]. **Meyer, D.L. (2008).** The poverty of constructivism.

Educational Philosophy and Theory, 41(3), 332-341. doi: 10.1111/j.1469-5812.2008.00457.x.

[22]. Miles, M., & Huberman, A. (1994). *An expanded sourcebook: Qualitative data analysis*. Thousand Oaks, CA: Sage Publications.

[23]. National Council of Teachers of Mathematics [NCTM]. (2000). *Principles and Standards for School Mathematics.* Reston, VA.: Author.

[24]. National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

[25]. National Science Foundation. (2005). *Foundations: A Monograph for Professionals in Science, Mathematics, and Technology Education* (Vol. 2): National Science Foundation.

[26]. Newmann, F., Bryk, A., & Nagaoka, J. (2001). *Authentic intellectual work and standardized tests: Conflict or coexistence?* Chicago: Consortium on Chicago School Research.

[27]. Phillips, D.C. (1995). The good, the bad, and the ugly: The many faces of constructivism. *Educational Researcher, 24*(7), 5-12.

[28]. Reed, D.K., and C. Groth (2009). "Academic teams promote cross-curricular applications that improve learning outcomes." *Middle School Journal 40*(3): 12-19.

[29]. van Zee, E.H., & Roberts, D. (2006). Making science teaching and learning visible through web-based "snapshots of practice". *Journal of Science Teacher Education, 17*(4), 367-388.

[30]. Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

[31]. Wilhelm, J.A., & Walters, K.L. (2006). Pre-service mathematics teachers become full participants in inquiry investigations. *International Journal of Mathematical Education in Science and Technology*, *37*(7), 793-804.

[32]. Xu, H., and L. Morris (2007). "Collaborative course development for online courses." *Innovative Higher Education. 32*(1): 35-47.

ABOUT THE AUTHORS

Patti Dyjur is an Instructional Designer and a Ph.D candidate at the University of Calgary.

Dr. Qing Li, is Associate Professor in the Faculty of Education at the University of Calgary. Her research interest includes Educational Technology, Mathematics Education, Technology Integration in math and science, equity, and cyberbullying.